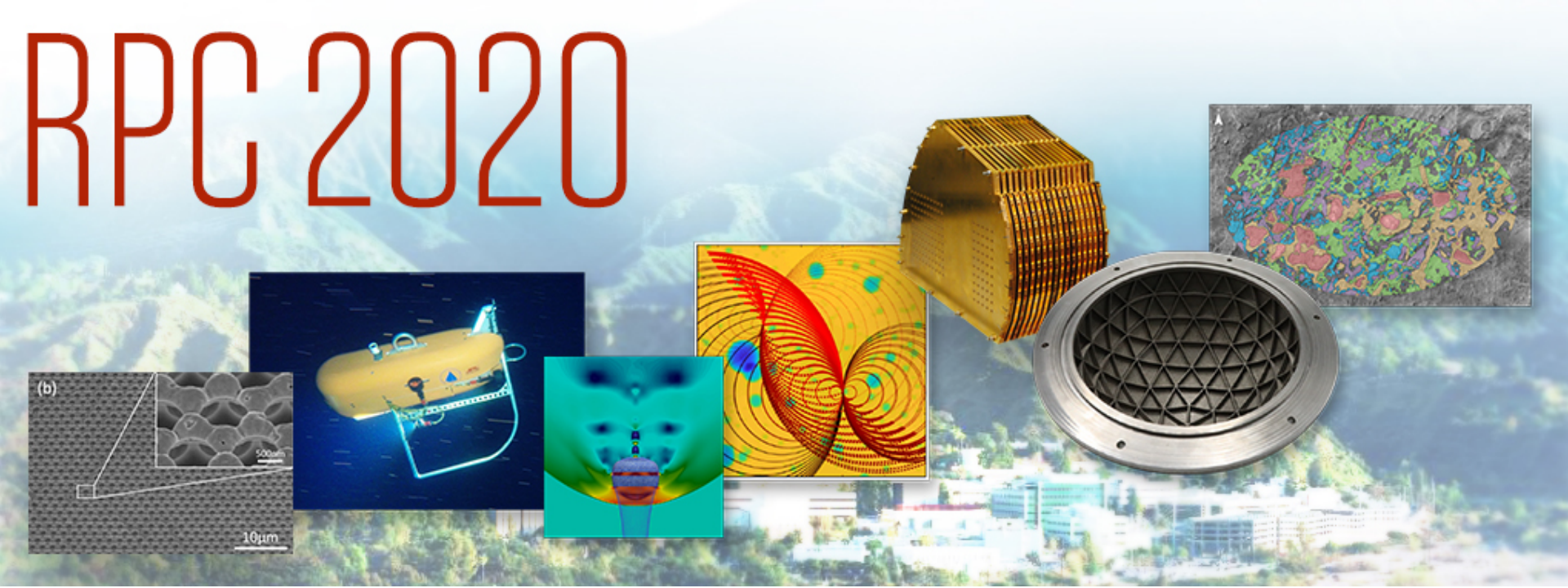


Virtual Research Presentation Conference

Detection and Characterization of Infrasound from Seismic Activity with Applications to Venus

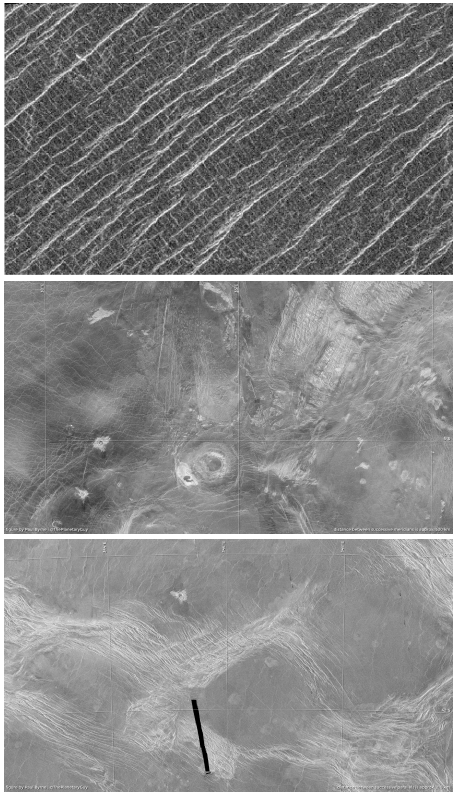
Principal Investigator: Siddharth Krishnamoorthy (335)
Co-Is: Quentin Brissaud (Seismo Lab, Caltech), Jennifer Jackson (Seismo Lab, Caltech), Attila Komjathy (335), James Cutts (404)
Program: Spontaneous Concept

Jet Propulsion Laboratory
California Institute of Technology

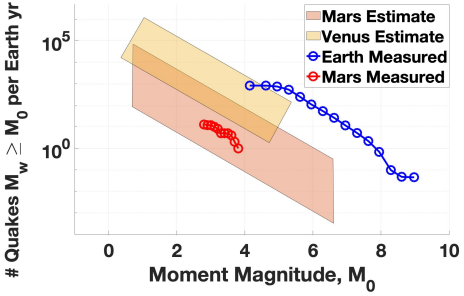
Assigned Presentation # RPC218

Introduction

- The surface of Venus has distinctive tectonic and volcanic character
- Heat flow estimates from Venus' mass and volume indicate Venus should be seismically and volcanically active
- Detection of seismic activity can establish if tectonism is still active and can be used to probe the crust and deeper parts of the planet
- Surface conditions are harsh, spacecraft lifetime is limited – no direct seismic measurements have been made



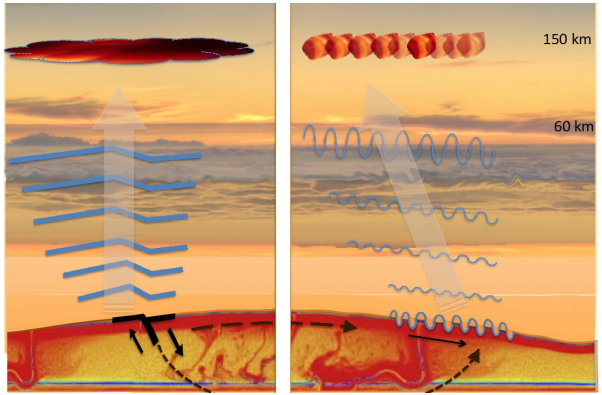
NASA (Magellan), 2020 and Byrne, 2018



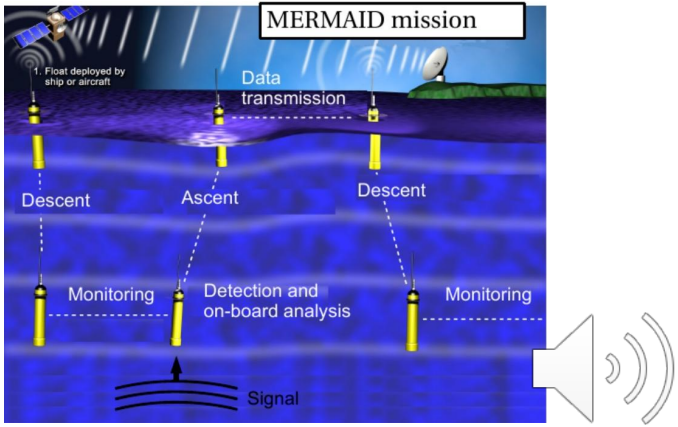
Data from Giardini et al., 2020 and Lognonne and Johnson, 2005

Introduction

- Energy from ground motion couples to the atmosphere-thermosphere-ionosphere system
- Seismo-acoustic coupling is 60x more efficient on Venus than the Earth
- Acoustic waves may be detected by barometers at 60 km altitude (~ 20 C and ~1 atm)
- Acoustic waves detected by hydrophones deployed in the Earth's oceans have led to the mapping of sub-ocean mantle plumes (Nolet et al., 2019)



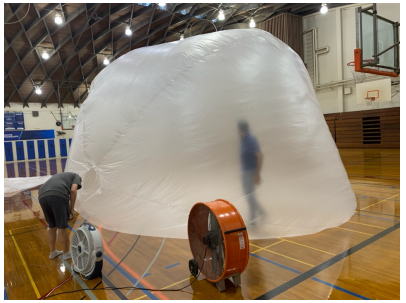
Cutts et al. (2015)

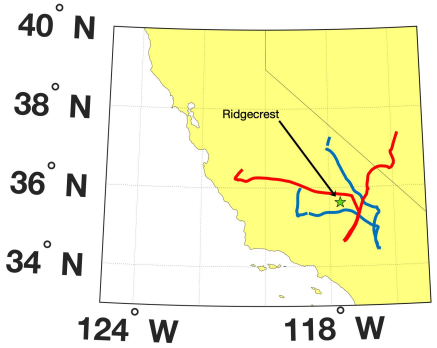


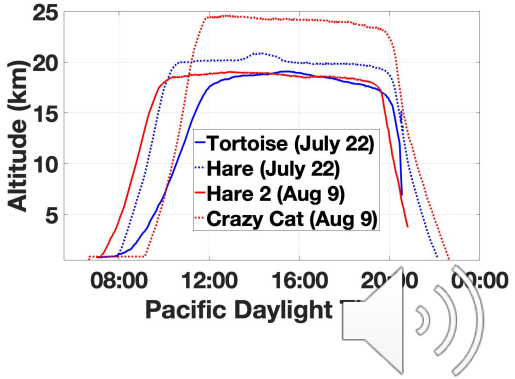
MERMAID Mission/Alex Sukhovich/www.argo.ucsd.edu (2019)

Problem Description

- This technique has never been demonstrated for a natural earthquake with a freely floating balloon.
- Two large quakes (M6.4 and M7.1) occurred at Ridgecrest, CA on July 4 and July 6, 2019. Nearly 4500 M>2.0 aftershocks in the next 6 weeks – opportunity to demonstrate this technique
- We manufactured, launched, and recovered 4 solar-powered balloons to overfly the Ridgecrest area on July 22 and August 9, 2019.
- This work deals with the analysis of data from those balloon flights, with ground-based data from USGS







Problem Description

- Objective#1:

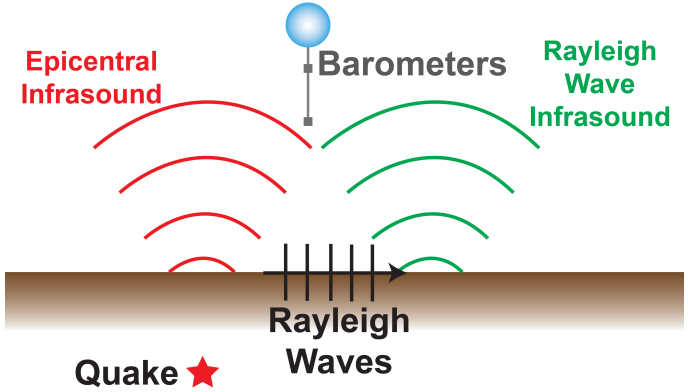
  Demonstrate the detection of natural seismic activity from balloon-based barometers in the Earth's atmosphere through seismo-acoustic infrasound (pressure waves with frequency < 20 Hz)

- Objective#2:

  Estimate the ground motion detection limit for Earth-balloon-based infrasonic detection of natural seismic and compute the preliminary detection limits on Venus using Venus atmospheric parameters

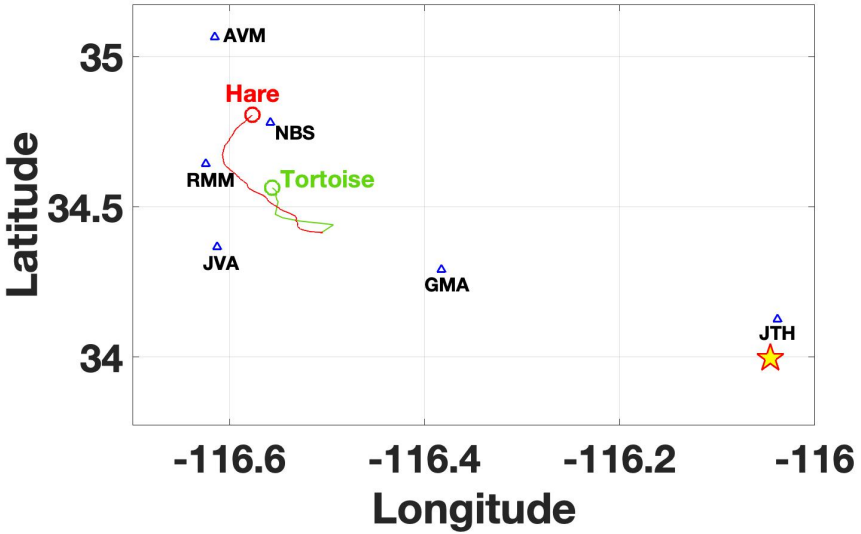
Methodology

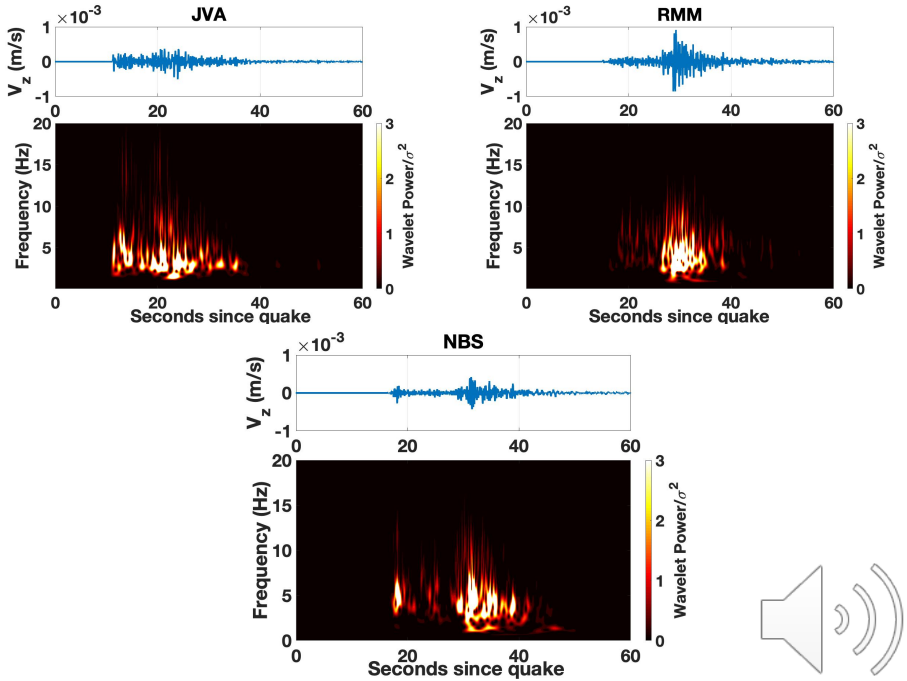
- 82 earthquakes of magnitude 1.5 – 4.2 occurred when the balloons were in flight (53 on July 22, 29 on August 9)
- List was narrowed to 13 events and split between “epicentral” and “Rayleigh wave” (RW) groups
- Analysis method:
  - Raytracing for epicentral group
  - Seismoacoustic simulation using Green’s function method (RW-atmos)
  - Comparison and scaling with USGS and SCEDC seismometers for RW Group
  - Higher fidelity simulation using SPECFEM-DG
  - Comparison of balloon data with ground stations and simulations



Results

First ever balloon-based natural earthquake detection (meets objective 1)



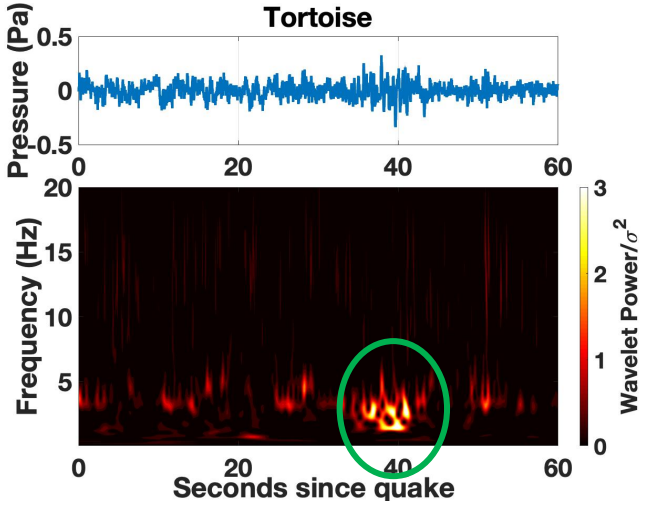


Magnitude 4.2, July 22, 2019 (USGS#38624623), 8 km depth, ~70 km away from the balloons

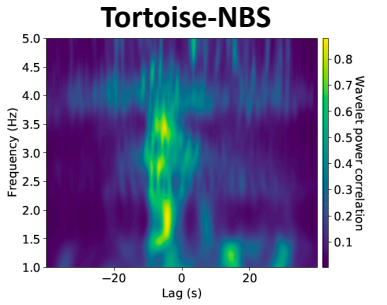
Results

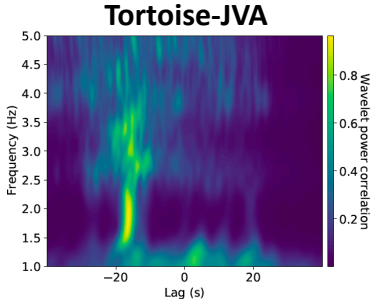
First ever balloon-based natural earthquake detection (meets objective 1)

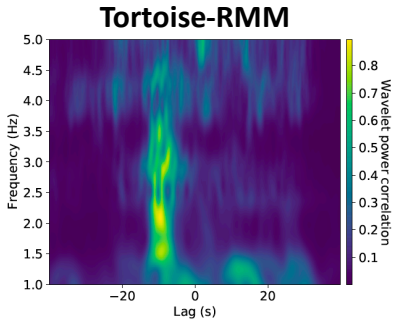
Strong correlation of barometer signal with three different ground stations and consistent arrival times

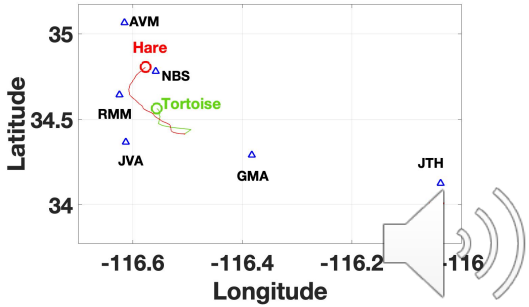


Balloon at 4.5 km altitude and rising



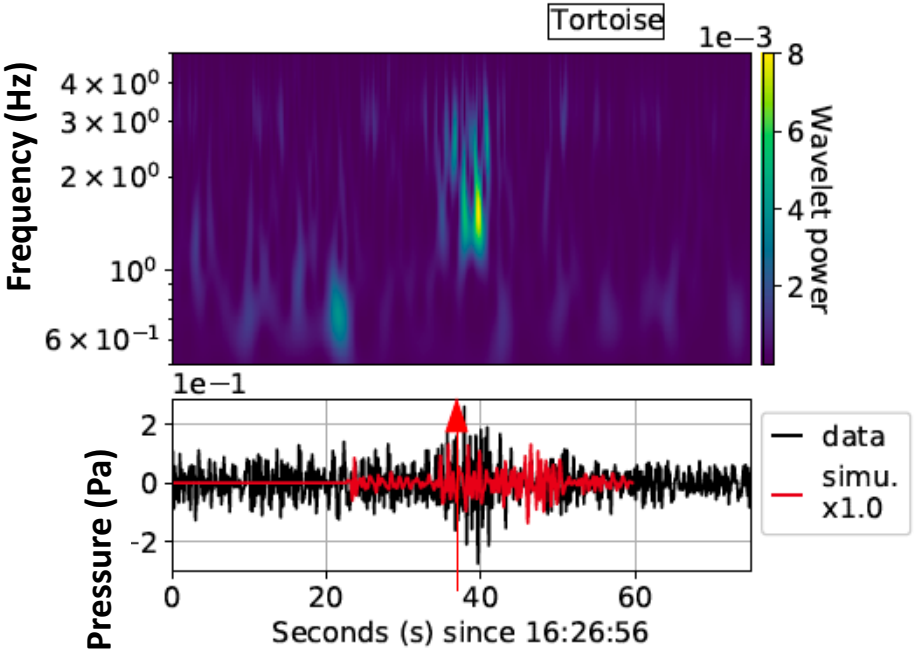


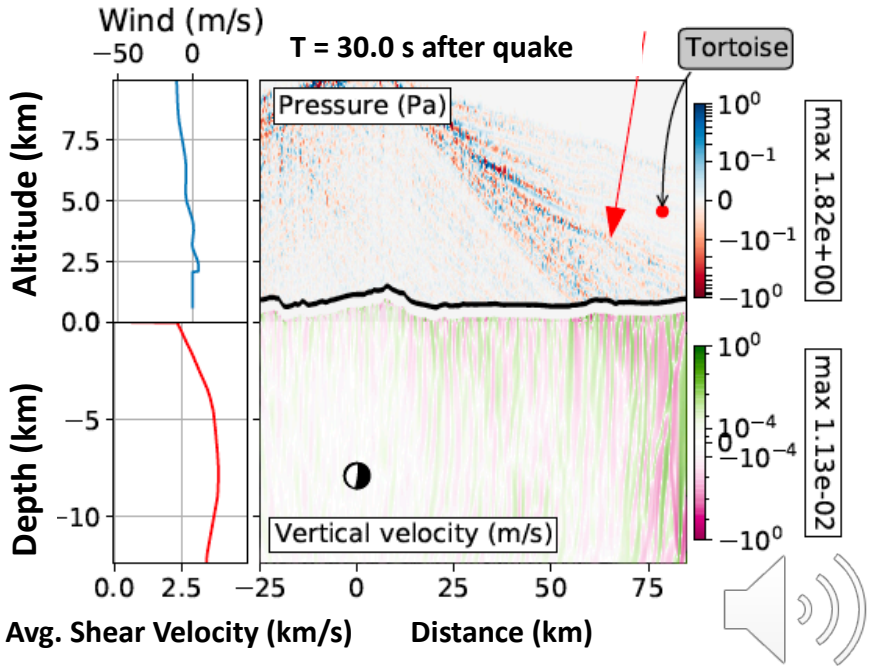




Results

First ever balloon-based natural earthquake detection (meets objective 1)

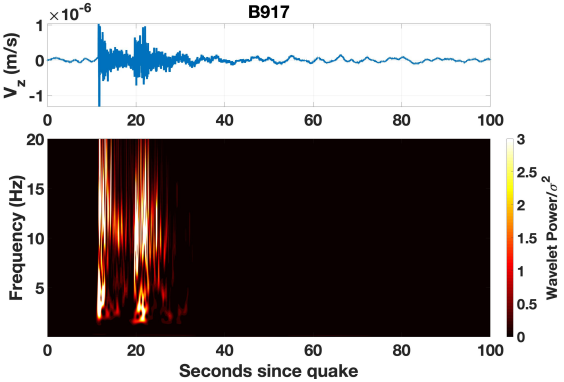




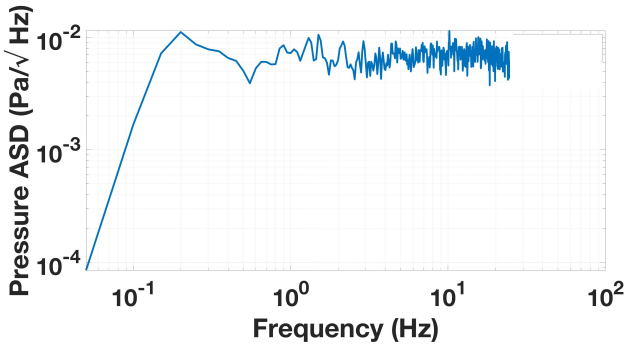
Good match with SPECFEM-DG simulation with topography and winds

Results

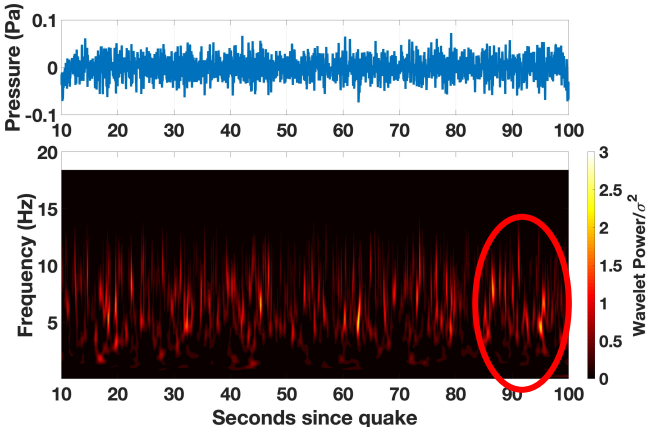
Earth stratosphere detection limit is > 1 μm/s amplitude for 0.008 Pa noise level



Seismometer near balloon



Balloon background noise level



Balloon pressure trace

Magnitude 2.1, July 22, 2019 (USGS#38625487), 2.8 km depth
Quake ~68 km away from the balloon, balloon at float (20.2 km altitude)

Venus preliminary estimate ~ 1/60 Earth limit = 0.016 μm/s (meets objective 2)

Acknowledgements

- We thank the JPL Strategic R&TD program for funding to conduct the flights and the ISC program for funds for the analysis.

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